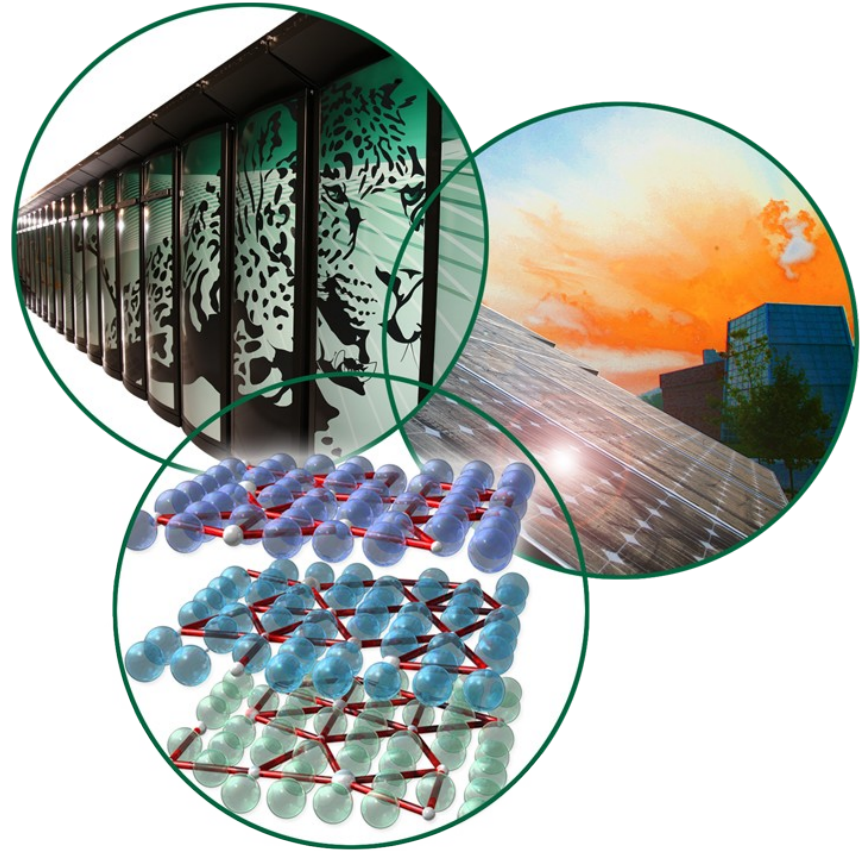# AFCI/NEAMS Nuclear Fuel Performance Integrated Code Project
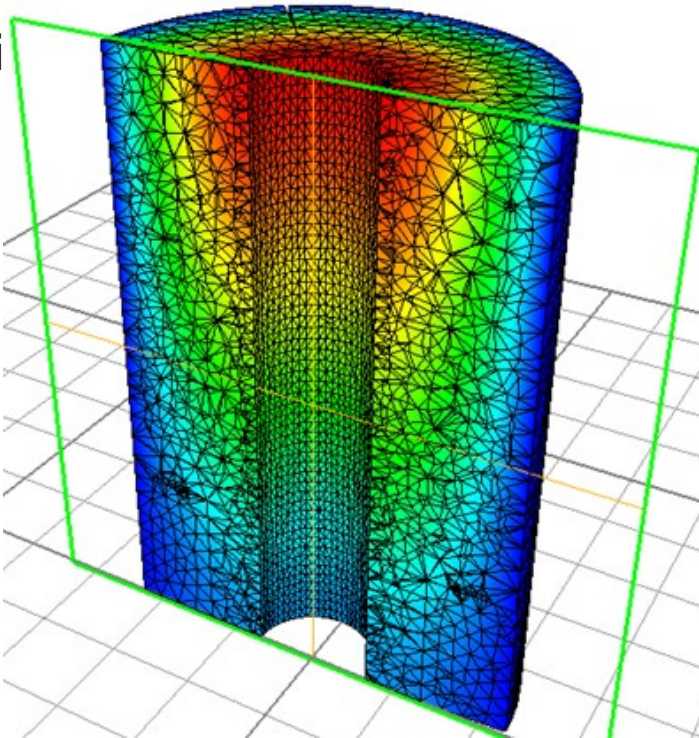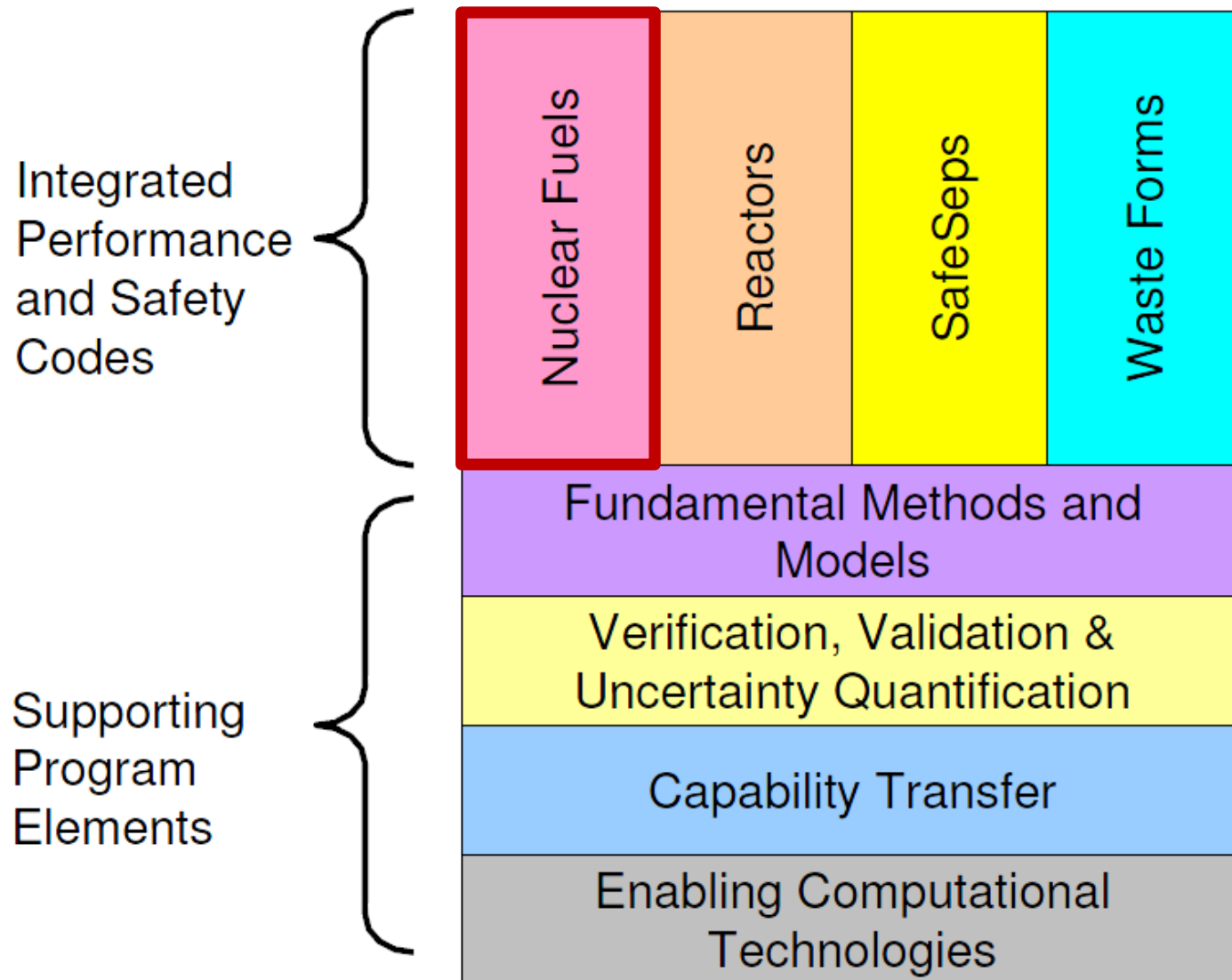
NEAMS Fuel IPSC Team
20 Aug 2009
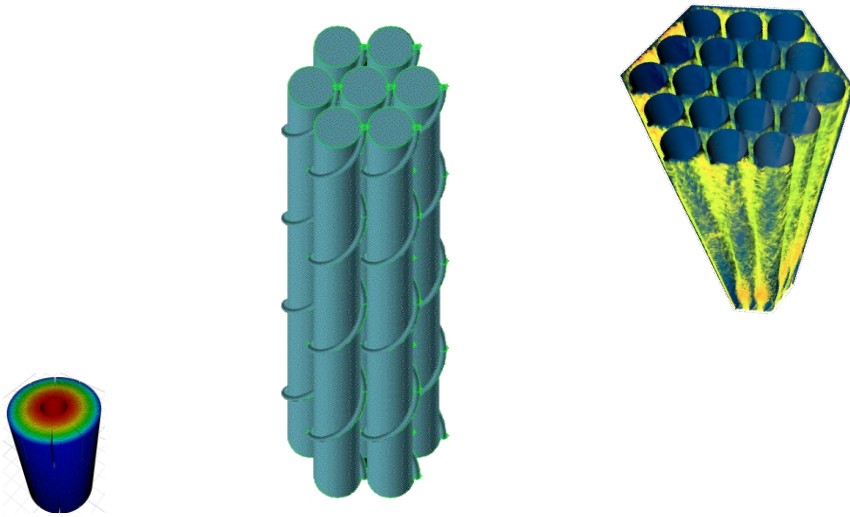
Click to edi

U.S. DEPARTMENT OF **ENERGY**
for the U.S. Department of Energy

OAK RIDGE NATIONAL LABORATORY
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Relationship of NEAMS Program Elements

Integrated Performance and Safety Codes

- Nuclear Fuels
- Reactors
- SafeSeps
- Waste Forms

Fundamental Methods and Models

Supporting Program Elements

- Verification, Validation & Uncertainty Quantification
- Capability Transfer
- Enabling Computational Technologies

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# NEAMS Fuel Performance Integrated Code Project Overview

- Click to edit the outline text format

  – Second Outline Level

- Third Outline Level

- Click to edit the outline text format

  – Second Outline Level

- Third Outline Level

  – Fourth Outline Level

- Click to edit the outline text format

  – Second Outline Level

- Third Outline Level

- Click Fourth outline Level

- Second Fifth Level

- Sixth

- Third Seven Level

 – Fourth Outline Eighth Outline
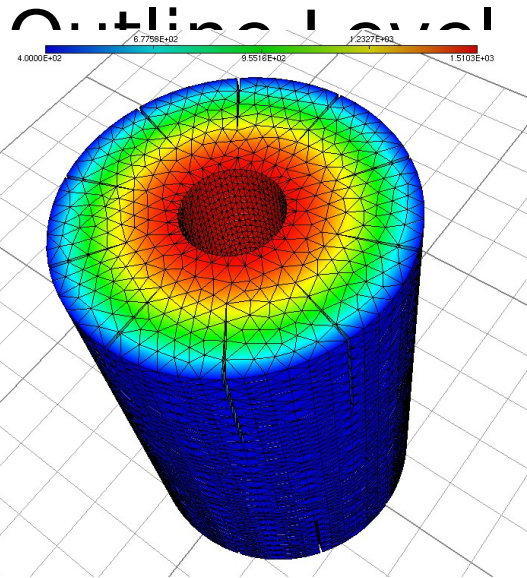
What's missing from that picture?

- geometry and mesh issues
  - different resolution meshes for different physics
  - different types of meshes for different physics
    - unstructured, Cartesian AMR, etc.

- numerical issues
  - required degree of coupling between physics
  - time-stepping
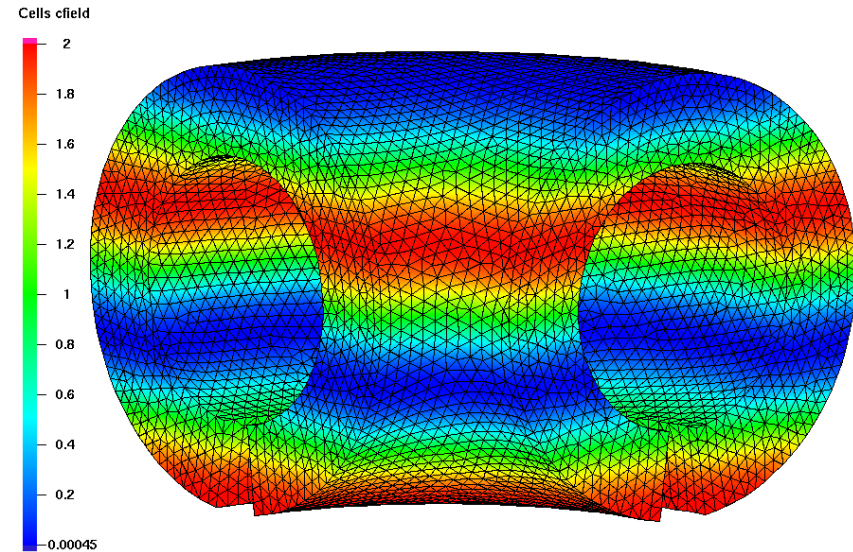
Tet mesh on curved geometry with source cell field quantities
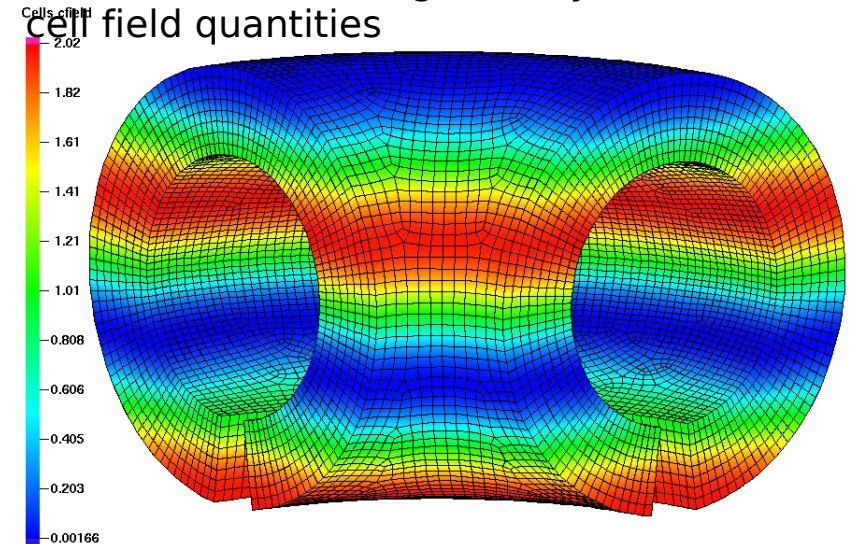
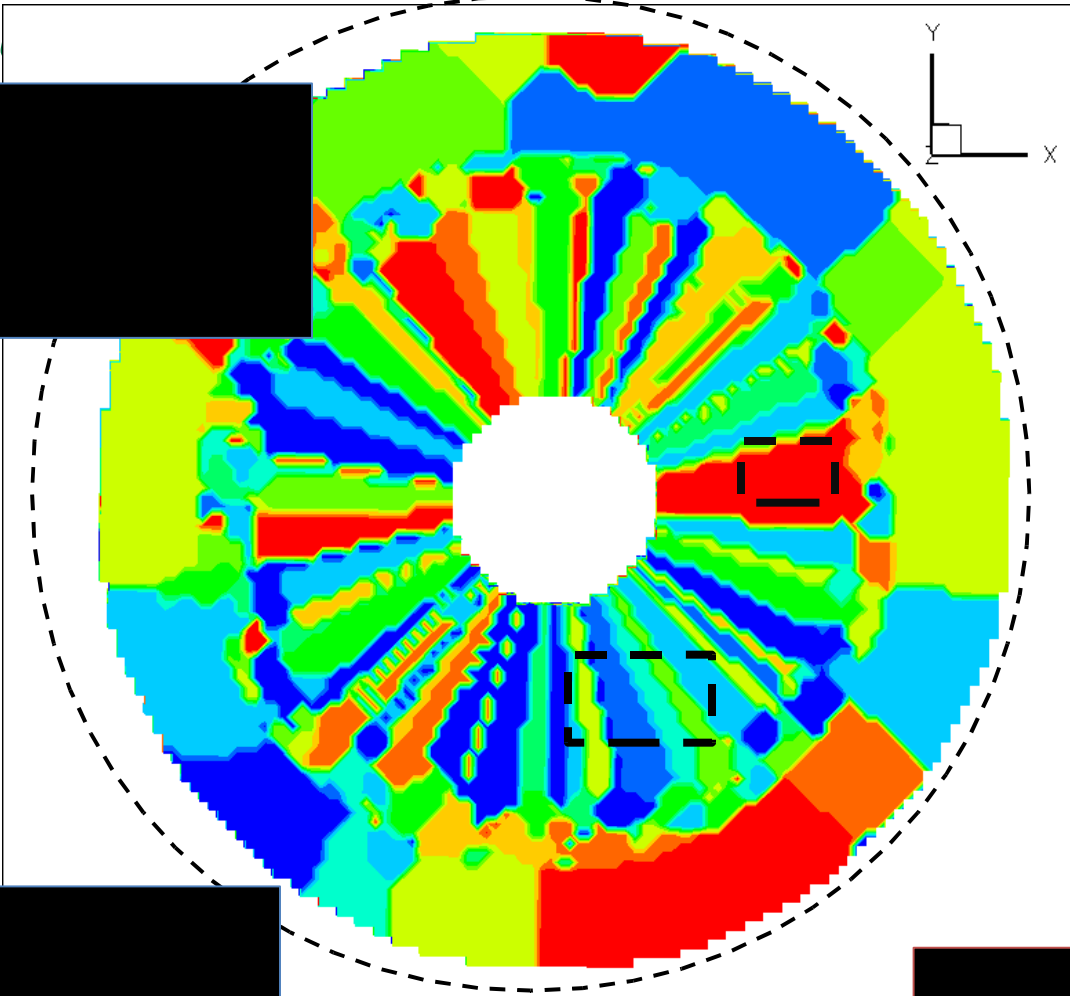Hex mesh on the same geometry with conservative cell mapped field

Integrated Simulation Approach

Different Models for Different Scales: Smaller Scales Inform Larger Scales

Example: Multi-Scale Efforts Within the Oxide Restruct
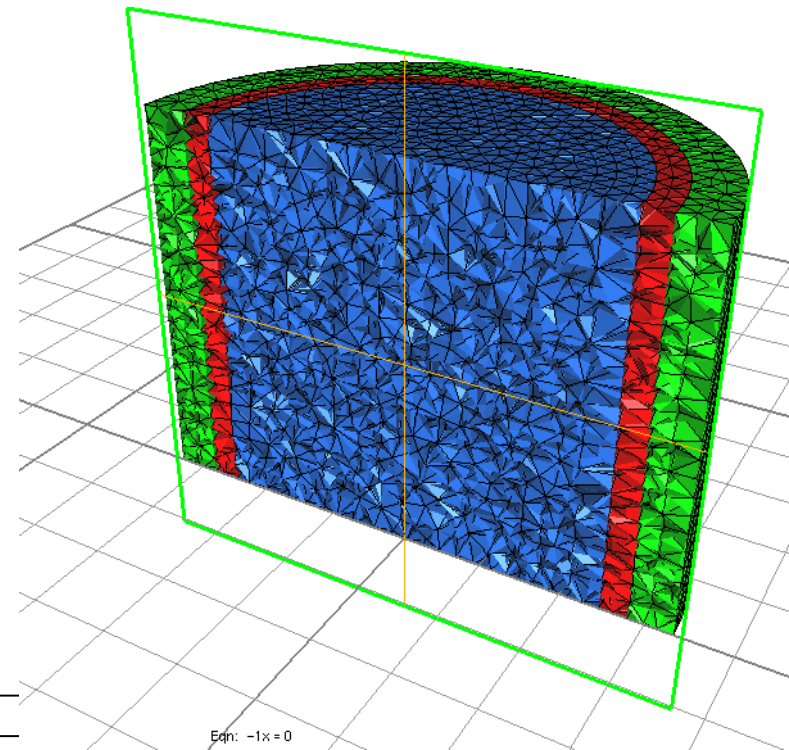
(IPSC)

(IPSC)

(FOA)

(FOA)

(FOA)

compare

upscale

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TP1: Fuel-Clad Gap Closure in Metal Fuels

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Eqn: −1x = 0

TP5: Species transport – metal fuel

- LANL developing species transport component (PEDERNAL)

  - coupled heat transport and species mass diffusion-reaction

  $$\frac{\partial \rho h}{\partial t} = \nabla \cdot K(T, \vec{\phi}) \nabla T + q(T, \vec{\phi}),$$

  - parallel (MPI)

  $$\frac{\partial \phi_i}{\partial t} = \nabla \cdot [D(T, \vec{\phi}) \nabla \phi_i + S(T, \vec{\phi}) \nabla T] + p_i(T, \vec{\phi}), \quad i = 1, \ldots, n.$$

  - advanced discreti

    - unstructured 3D meshes
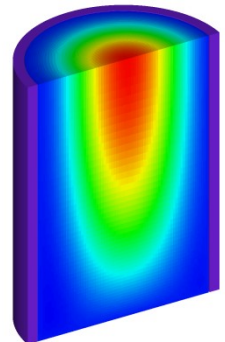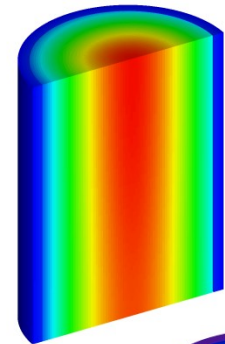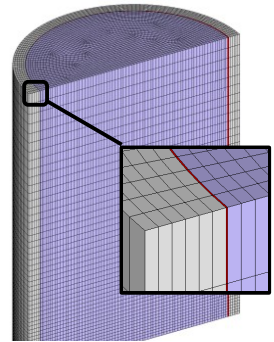
    - mimetic FD, mixed-hybrid FE

  - advanced time integration

    - fully-coupled 2nd order implicit (BDF2)

    - adaptive step sizes from a priori local time error estimates
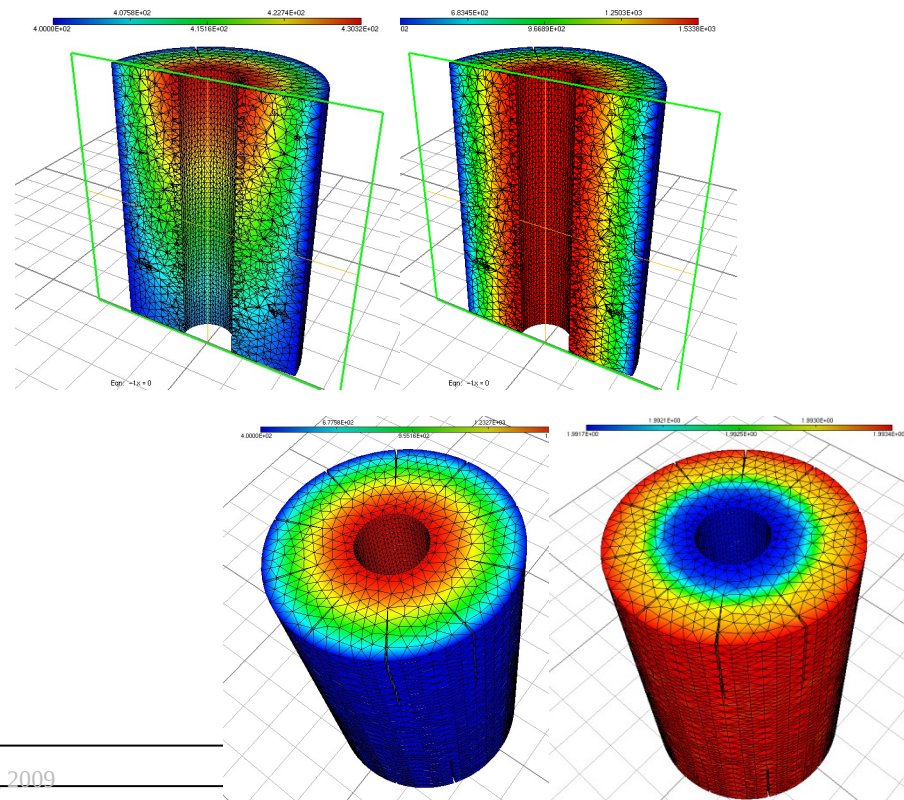
  - advanced nonlinear solver

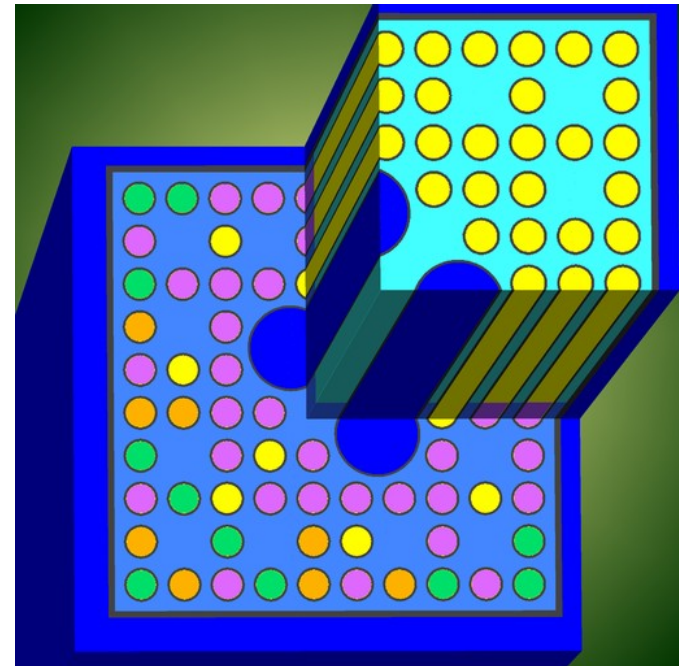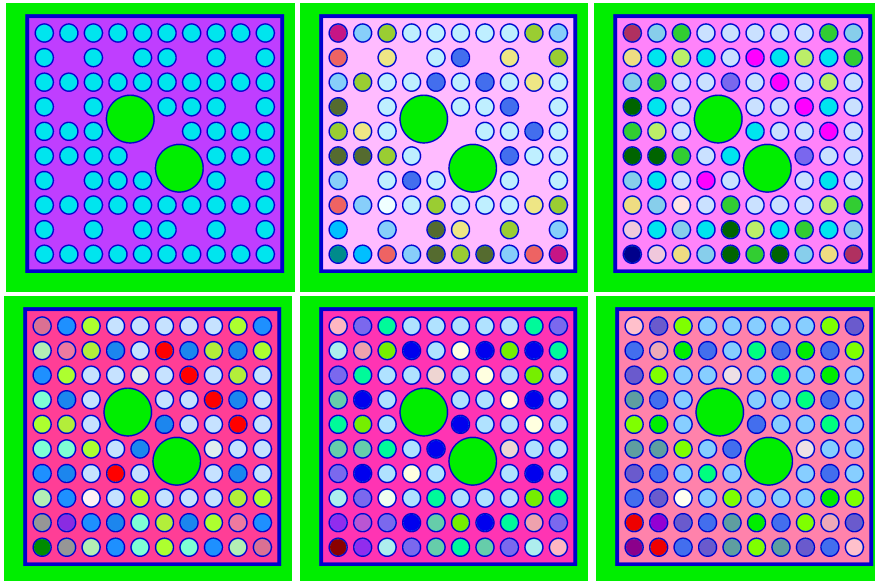   - nonlinear Krylov accelerated inexact Newton (not JFNK)

    - decoupled physics-based preconditioning via

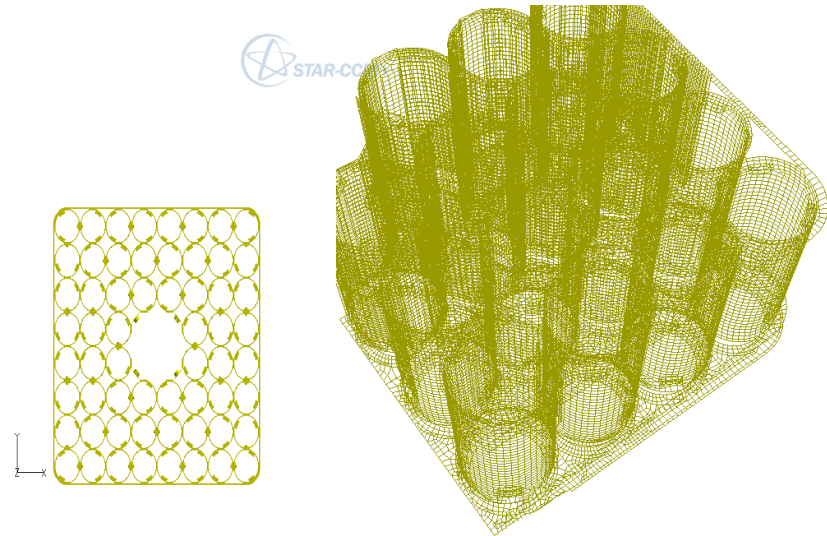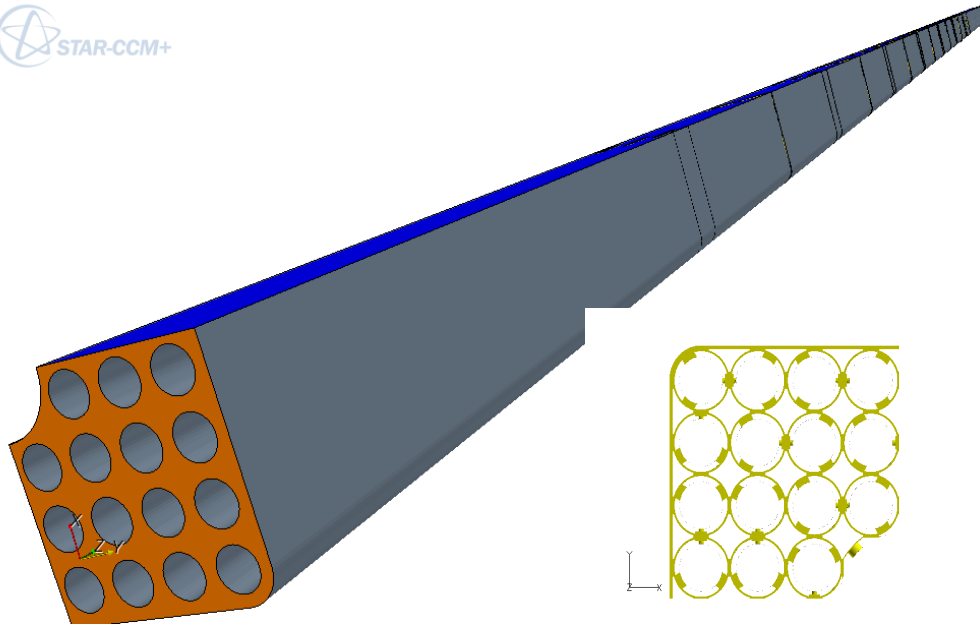# TP2: FCMI Simulation of Oxide Fuel Pellet

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TP3: Power & Mechanics in a BWR Bundle

TP4: 3D Flow Effects - BFBT

- single mesh block: ~3 million zones
- entire assembly: ~ 25

Summary of approach

- develop 3D thermo-mechanics, neutronics, flow capability
  - initially prototype based on existing code(s)
  - ultimately component-based mesh-centric design, in collaboration with CT Program Element

- incorporate sub-grid models
  - initially using existing models
  - incorporate improved sub-grid models based on FOA and later FMM Program

28-Aug-2009